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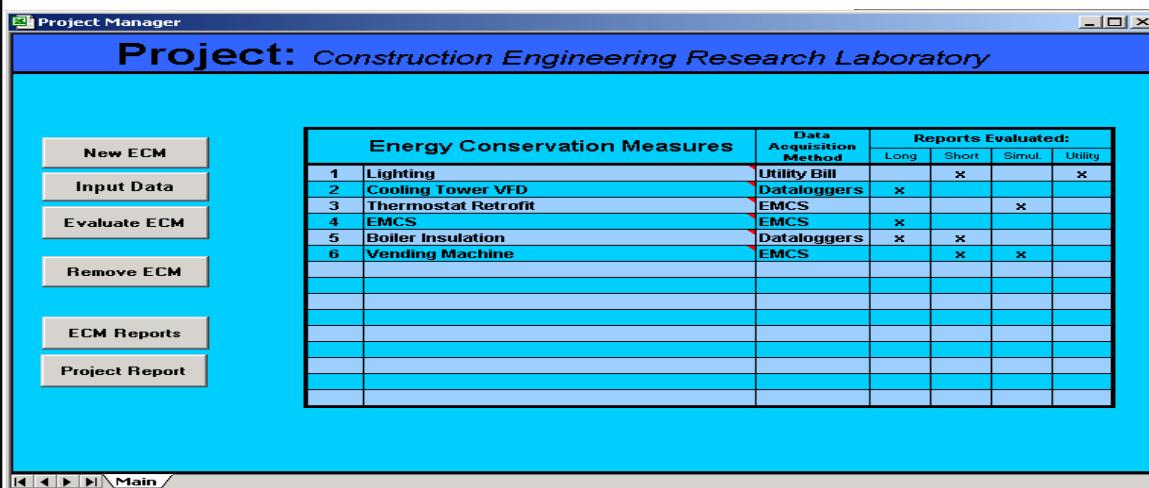
Engineer Research and Development Center

Energy Savings Measurement and Verification Toolkit Guide

Version 2.96

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Final Report

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ABSTRACT: The Measurement and Verification (M&V) Toolkit is a set of spreadsheets and macros that can be used to estimate M&V costs. It allows a user to determine what method of monitoring will provide the necessary data at an acceptable cost. The toolkit estimates costs for four M&V methods (organized by methods of gathering data), each compatible with IPMVP 2001 and AHRAE Guideline 14 standards. The methods included are: long-term analysis, short-term analysis, monthly utility bill analysis, and a calibrated simulation model. Summaries of costs for various methods can be easily compared using built in report summaries.

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Conversion Factors

Non-SI^{*} units of measure used in this report are converted to SI units as follows:

Multiply	By	To Obtain
acres	4,046.873	square meters
cubic feet	0.02831685	cubic meters
cubic inches	0.00001638706	cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(5/9) x (°F – 32)	degrees Celsius
degrees Fahrenheit	(5/9) x (°F – 32) + 273.15.	kelvins
feet	0.3048	meters
gallons (U.S. liquid)	0.003785412	cubic meters
horsepower (550 ft-lb force per second)	745.6999	watts
inches	0.0254	meters
kips per square foot	47.88026	kilopascals
kips per square inch	6.894757	megapascals
miles (U.S. statute)	1.609347	kilometers
pounds (force)	4.448222	newtons
pounds (force) per square inch	0.006894757	megapascals
pounds (mass)	0.4535924	kilograms
square feet	0.09290304	square meters
square miles	2,589,998	square meters
tons (force)	8,896.443	newtons
tons (2,000 pounds, mass)	907.1847	kilograms
yards	0.9144	meters

* *Système International d'Unités* ("International System of Measurement"), commonly known as the "metric system."

Preface

This study was conducted for the Directorate of Military Programs, Headquarters, U.S. Army Corps of Engineers (HQUSACE) under Project AT45, "Energy and Energy Conservation"; Work Unit 008BEQ, "Energy Project Measurement and Verification." The technical monitor was Hank Gignilliat, DAIM-FDF-UE.

The work was performed by the Energy Branch (CF-E) of the Facilities Division, Construction Engineering Research Laboratory (CERL). The CERL Principal Investigator was David Underwood. Part of this work was done by Texas Engineering Experiment Station, 332 Wisenbaker Engineering Research Center, College Station, TX 77843 under contracts No. DACA42-03-P-0102 and No. DACA42-01-F-0098. The technical editor was William J. Wolfe, Information Technology Laboratory. Dr. Thomas Hartranft is Chief, CEERD-CF-E, and Michael Golish is Chief, CEERD-CF. The associated Technical Director was Gary W. Schanche, CEERD-CV-T. The Director of CERL is Dr. Alan W. Moore.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL James R. Rowan, and the Director of ERDC is Dr. James R. Houston.

1 Introduction

Background

The Federal government annually spends billions of dollars in energy costs (\$7.4 billion in 2000). Building systems account for a significant portion of these high costs, run at less than optimum efficiency. Replacing old and inefficient equipment with newer, better equipment can reduce energy expenditures. Moreover, government agencies can make such building improvements entirely without capital investments if the improvement project uses an Energy Savings Performance Contract (ESPC). ESPCs make energy conservation a more viable option for cash-strapped agencies because the contractor absorbs initial costs, which are repaid later through utility bill savings. However, as in all energy savings projects, it is necessary to measure and verify the actual savings if the realized savings are to be known. This is especially critical for ESPCs, because, by law, only verified energy savings can be used to pay for ESPC Costs. A measurement and verification (M&V) plan must be custom tailored to each project to ensure that it is cost effective and meaningful.

The M&V Toolkit described in this report is a utility that can be used to estimate M&V costs. The Toolkit allows users to determine the monitoring method that will provide the necessary data at an acceptable cost. The basis for the M&V toolkit was originally developed by the Energy Systems Laboratory (ESL) at Texas A&M University (Haberl 2003b). It was later expanded and modified at the Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC/CERL). The toolkit estimates costs for four M&V methods (organized by methods of gathering data), each compatible with IPMVP 2001* and AHRAE Guideline 14 standards.† The methods included are a long-term analysis, a short-term analysis, a monthly utility bill analysis, and a cali-

* *International Performance Measurement and Verification Protocol* (U.S. Department of Energy [USDOE], Washington, DC, 2001).

† American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Guideline 14-2002, *Measurement of Energy and Demand Savings* (ASHRAE, Atlanta GA, 2002).

brated simulation model. The toolkit is based on a collection of Microsoft Excel workbooks, with automated cost data entry and evaluation. This report provides an overview of the project, and is a user manual for the cost-estimating toolkit.

Intended Users

The M&V Toolkit can be used by a variety of people. An Energy Manager, for instance, might use it to check the reasonableness of a contractor cost estimate for M&V activities. An ESPC contractor may use it to estimate its M&V costs to include in an ESPC proposal. A consultant may use it to provide cost estimates to any number of customers M&V. Any one of these persons might use the tool to explore various M&V scenarios and the related costs.

Objective

The objective of this work was to provide a user-friendly method of quickly estimating M&V costs for various energy conservation methods (ECMs) and M&V options, to determine the most cost effective monitoring method.

Approach

A set of spreadsheets was created and linked to each other via formulas. Macros were programmed to automate data entry, data analysis, and report generation. The Texas Engineering Experiment Station (TEES) was contracted to populate the spreadsheets with data from several ESPC M&V projects.

Mode of Technology Transfer

The information in this report will be used by government and commercial planners to determine appropriate M&V plan for their specific projects.

This report will be made accessible through the World Wide Web (WWW) at URL:

<http://www.cecer.army.mil/mvtoolkit>

2 Installation Guide

System Requirements

This toolkit requires Microsoft Excel 2000 or higher, and at least 10MB of hard disk space. Additional space is required for each project.

Installation Instructions

Note: these instructions are specific assume WinZip^{*} as the extraction utility;. They are, however, general enough to apply to most file compression utilities.

1. Double-click the current *.zip archive containing the toolkit (Figure 1). The archive will open and the contents will be displayed in your extraction utility. (If you do not have one, several are available for free download on the Internet, such as WinZip.)
2. Click the “Extract” button to extract the files.

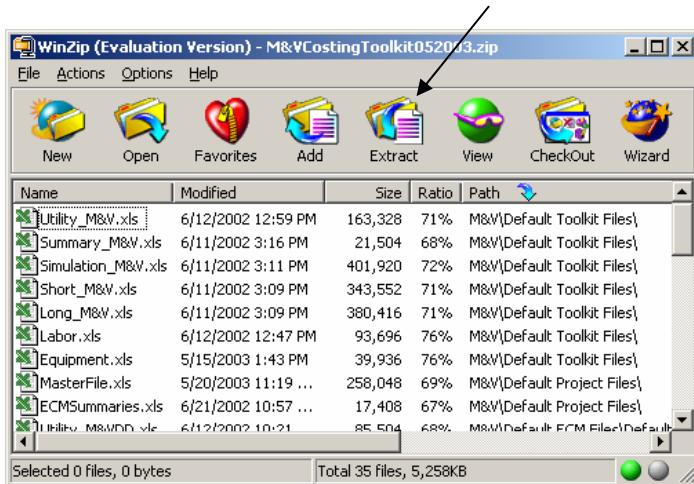


Figure 1. List of zipped files.

* WinZip is a commercial file-compression utility that operates under the Windows® operating system. An evaluation version of WinZip is available for free download through URL: <http://www.winzip.com/>

3. Using the “Folders/drives” section of the extract form, select the directory to which you would like to install the toolkit (Figure 2). Below the “Files” heading, two options should be selected: “All files” and “Use folder names.”

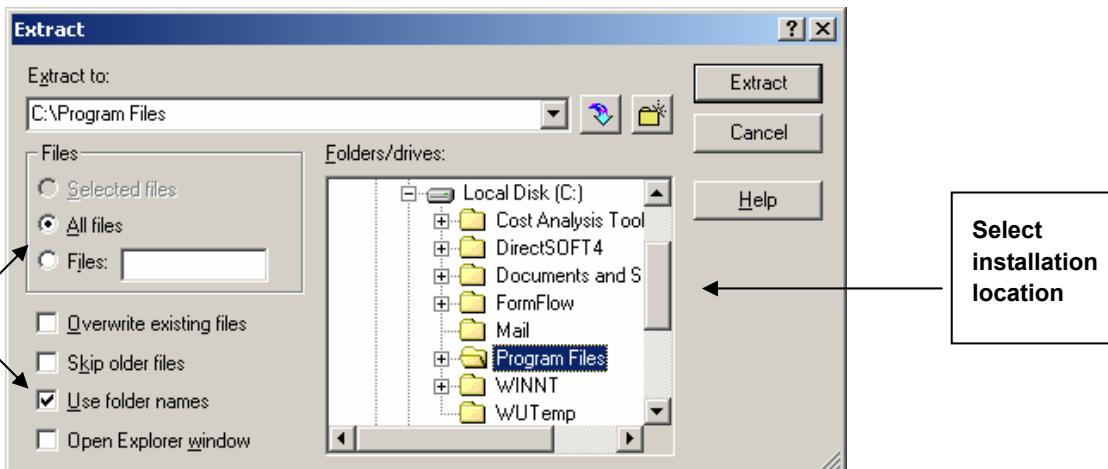


Figure 2. Setting extraction options.

4. Click the “Extract” button on the form to install the toolkit to your selected directory.

After following these four steps, a new folder, “M&V,” will be located in the directory you selected in step 3 (Figure 3). For example, if, in step 3, you selected “C:\Program Files,” then after extracting a new directory, the path “C:\Program Files\M&V Toolkit” would exist. The “M&V Toolkit” folder contains the costing toolkit.

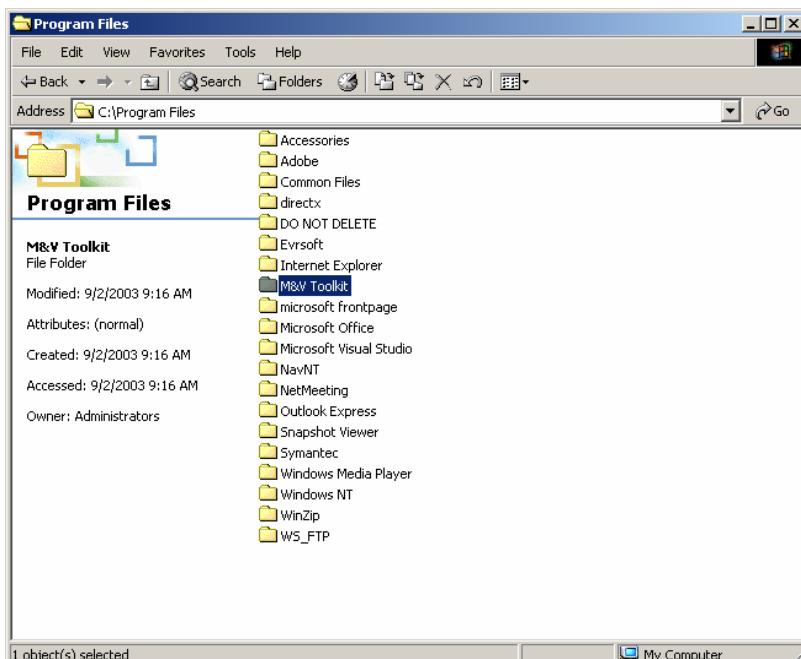


Figure 3. Typical directory tree listing after installation.

3 Overview

This chapter provides an introduction to the main Excel workbooks used in the Toolkit. Data is entered into various workbooks in sequential steps that generally follow the order shown in Figure 4.

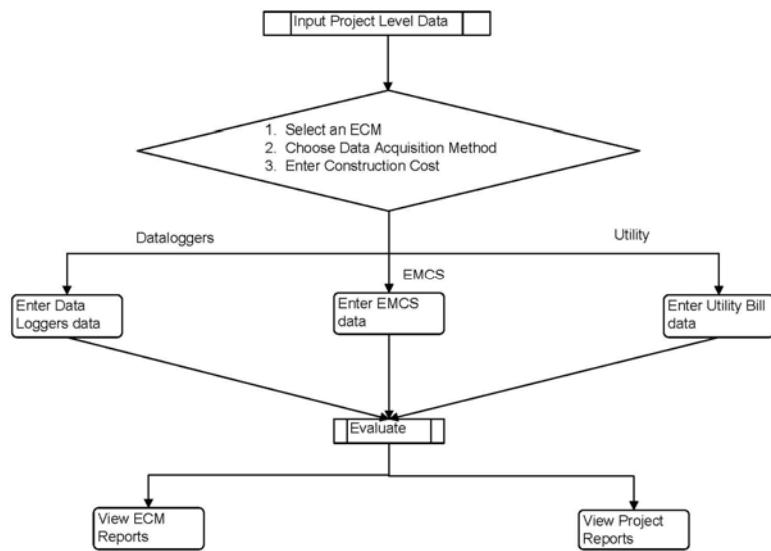


Figure 4. Using the toolkit.

Toolkit Uses

The Toolkit has many uses. Estimating M&V costs is obviously the end result of the Toolkit calculations. The process of entering data for those calculations and the bottom line results, however, have several other uses. While using the Toolkit, the user will find themselves thinking through the M&V process. Determining what data logger to use, for instance, requires the user to reflect on how many channels are required, how often the data needs to be collected, what sensors are needed, and many other details that are part of developing the M&V plan. This in turn prompts the user to consider alternatives and make comparisons between those alternatives. Considering these alternatives before evaluating a proposal gives the user a basis for comparing proposals and asking the contractor why certain alternative were (or were not) considered. (The person evaluating M&V cost proposals is in a much better position to negotiate costs if

they have their own cost estimate to use as a negotiation tool.) Because the Toolkit has default costs for ECM equipment and labor, users that want a very quick estimate can develop one.

You will encounter four main workbooks/workbook types in the toolkit:

1. ***The M&V Toolkit*** file is the first file found in the root M&V Toolkit folder. The M&V toolkit file is used to access the Project Manager,
2. ***The Project Manager*** keeps track of all the ECMs in a project and allows you to add, modify, and remove ECMs, and to enter all the necessary data for a project. From the project manager, you will access the other two main workbook types: data input and report workbooks.
3. ***Data input.*** There are many data input workbooks, all of which look similar. These workbooks are opened from the “Input Data” button, and allow you to enter various cost data for a project or ECM.
4. ***Report workbooks.*** There are also several report workbooks, each of which provide an overview of a certain aspect of an ECM or project, giving useful summaries of your project.

The toolkit features cost-estimation tools for four distinct M&V methods: long, short, utility, and simulation:

1. The long M&V method refers to the process of collecting and analyzing data over a period of several years. This method may be more appropriate to use when variations in facility operations are expected.
2. The short M&V method refers to the process of collecting and analyzing data over a period of several months. This method may be more appropriate to use when variations in operations are not expected.
3. The utility M&V method refers to collection and analysis of utility bills. If the ECM will have a large impact on the reduction of power consumption, this method is appropriate to use for M&V.
4. Simulation M&V (e.g., *Energy Plus*,^{*} etc.) could be used for buildings in which multiple ECMs will be installed or where tracking complex building operation conditions is necessary.

* EnergyPlus is “Building Energy Simulation Software” for modeling building heating, cooling, lighting, ventilating, and other energy flows. Energy Plus software is available from the U.S. Department of Energy through URL: <http://www.eere.energy.gov/buildings/energyplus/>

M&V Toolkit Organization

The M&V Toolkit file is the user-interface of the application. From this file you can create, open and modify, and delete projects (Figure 5). Although transparent to the user, these functions are performed by macros.

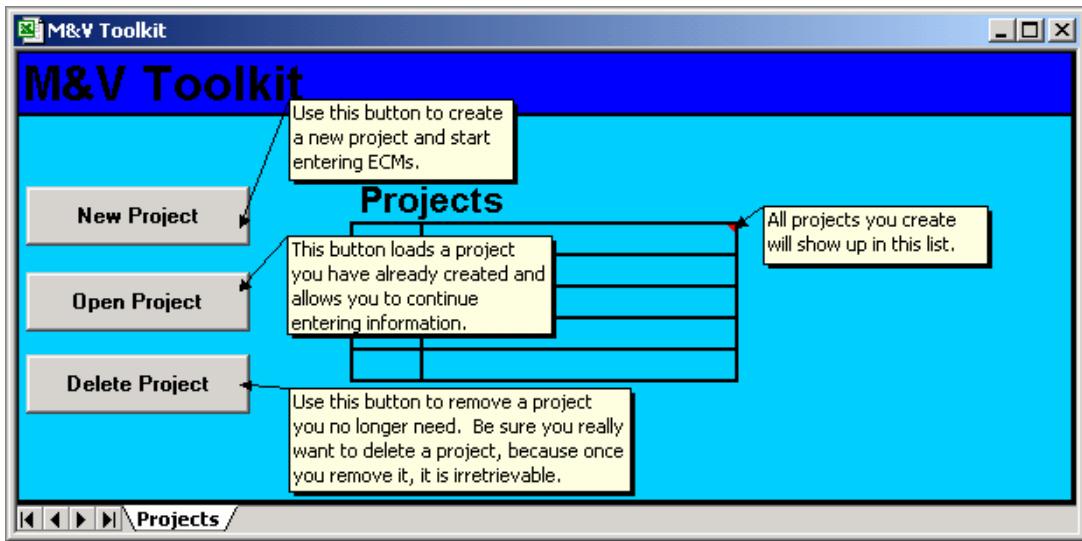


Figure 5. The M&V Toolkit window.

Project Manager

The Project Manager (Figure 6) is where you will spend the most time in the toolkit. Each project has its own Project Manager. From here you can add or remove ECMs, enter or modify cost data, and compile and view reports for your projects. The files needed to enter or modify data are automatically copied(deleted) to(from) the appropriate directories when you add(remove) ECMs. Similarly, the files needed to compile and view reports are automatically copied to the appropriate directories when you compile reports.

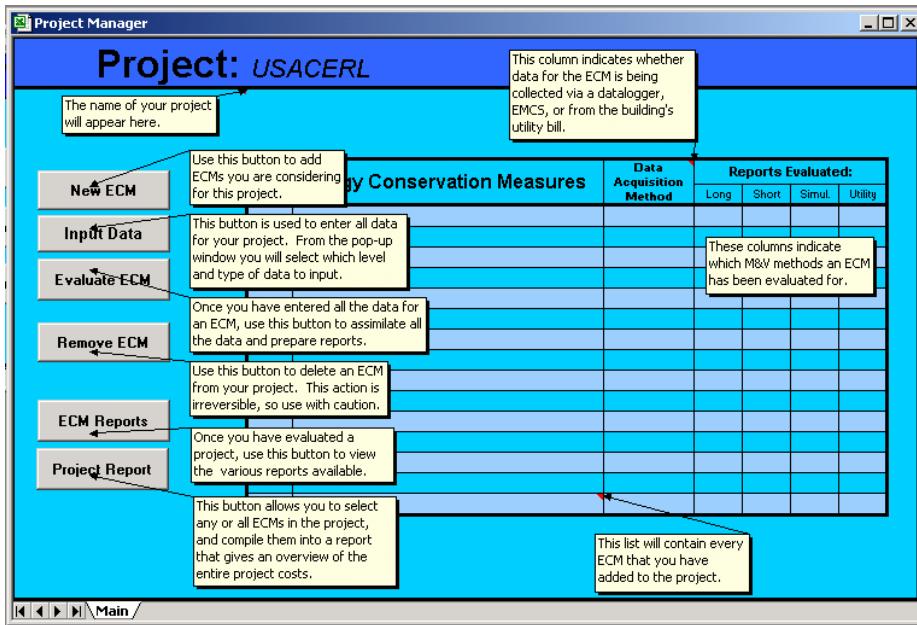


Figure 6. The Project Manager window.

Data Input

Five data input workbooks are available from the “Input Data” button in the Project Manager (e.g., Figure 7). Each allows you to enter certain data for a project. Two of the data input workbooks are specific to the project, and the other two are unique for each ECM in the project. The toolkit manages all these data books through the Project Manager interface. Data can be entered into these workbooks using the “Input Data” button located in the upper right corner of each sheet.

Data Manipulation Costs: Short M&V - Data Loggers

No of Channels	0			
No. of Loggers	0			
Polling, QC and Data Entry Costs				
Item	A. Unit	B. Supply	E. No. Per yr	
		No. Unit	\$/Unit	
Setup Costs	Per Channel	0	\$0.00	1
Polling Costs	Per Logger	0	\$0.00	52
QC, Database Load	Per Channel	0	\$0.00	50
Data Cleaning	Per Channel	0	\$0.00	1
Computer Maintenance	Per Month	12	\$1.00	12
other		0	\$0.00	0
Data Recovery/Missing Data				
Item	A. Unit	B. Supply	E. No. Per yr	
		No. Unit	\$/Unit	
Data Recovery	Per Channel	0	\$1.00	1
Missing Data	Per Channel	0	\$1.00	1
other		0	\$0.00	0
One Time Baseline/Post Retrofit Analysis				
			E. No.	
<input type="button" value="Long M&V"/> <input type="button" value="Short M&V"/> <input type="button" value="Simulation M&V"/>				

Ongoing Savings Analysis				
Item	A. Unit	B. Supply	E. No. Per yr	
		No. Unit	\$/Unit	
Post-Retrofit Model Costs		4	\$1.00	1
Savings Calculations		4	\$5.00	12
other		0	\$0.00	0

Reporting				
Item	A. Unit	B. Supply	E. No. Per yr	
		No. Unit	\$/Unit	
Setup Costs		0	\$1.00	1
Report Generation Costs		0	\$1.00	12
other		0	\$0.00	0

Close-out, Data Transfer			
			E. No.
<input type="button" value=" <"/> <input type="button" value="> "/> <input type="button" value=" <> "/> <input type="button" value=" >> "/>			

Figure 7. A data input sheet.

Cost Reports

After an ECM has been created and evaluated, various reports become available. These can be viewed using the “ECM Reports” and “Project Report” buttons on the Project Manager. Which reports are available depends on the Data Acquisition method of the ECM and on the M&V methods for which the ECM has been evaluated. Figure 8 shows a sample cost report for passive solar hot water.

Equipment Costs: Long M&V			
Project: CERL			
ECM: Passive Solar HW			
Data Acquisition Method: Data Loggers			
Item	Cost/Item	No. Items	Total Cost
Logic Beach, Inc. - HyperLogger/Power Supply	\$4,093.00	1	\$4,093.00
Istec Corp. (Ista) - 1805-5/G	\$196.00	1	\$196.00
Kele Solutions - SCT-2000	\$137.04	4	\$548.16
The Eppley Laboratory - Model ST-3	\$2,900.00	1	\$2,900.00
Total Cost			\$7,737.16

Figure 8. A cost report sheet.

4 Tutorial

This chapter provides a step-by-step tutorial on how to use the toolkit. It guides the user through creating a project, adding ECMs, customizing the data, evaluating reports, and viewing the results.

Examples of The Toolkit In Use

To give potential users a feel for use of the Toolkit, several M&V scenarios were used to enter data into the Toolkit. This was done with a previous version of the Toolkit, so a direct and exact correlation between these examples and the current version (2.96) is not possible. They do, however, provide real and reasonable examples of values used to populate the Toolkit. The examples include energy savings projects such as Lighting, Chillers, EMCS, and Boiler retrofit. Each energy savings project has multiple examples of M&V scenarios ranging from simple less extensive M&V to more extensive M&V. A total of 13 scenarios are presented. These examples are documented in Haberl et al. (2003b).

Starting Off

To begin using the toolkit, locate the folder in which you installed the application (see chapter 2 for installation instructions). Once you have located the “M&V Toolkit” folder (Figure 9), double-click the “M&V Toolkit.xls” file inside.

A splash screen will appear, followed by the M&V Toolkit window.

Creating a New Project

To start a new project, click the “New Project Button.” A pop-up window will ask you to enter a name for your project (Figure 10). Project names must be longer than one character, may not contain special characters [~], [/], [:], [*], [?], [<], [>], or [|], and may not end in a space. Type the name of your project and press “Create.”

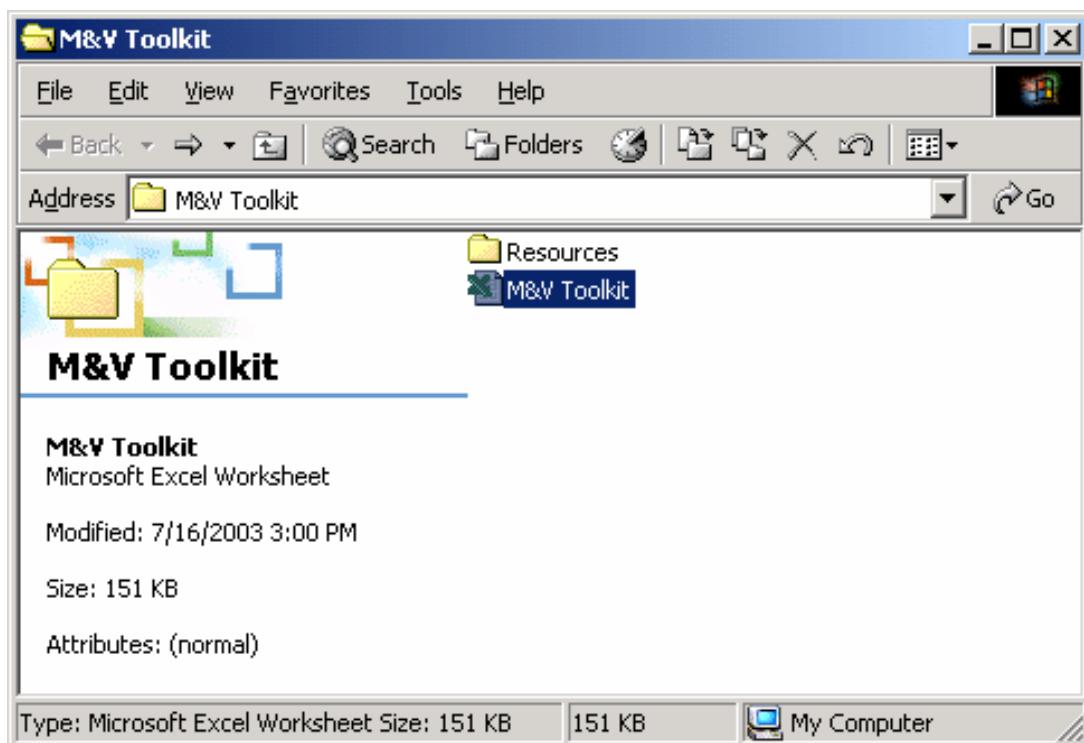


Figure 9. The M&V Toolkit folder.

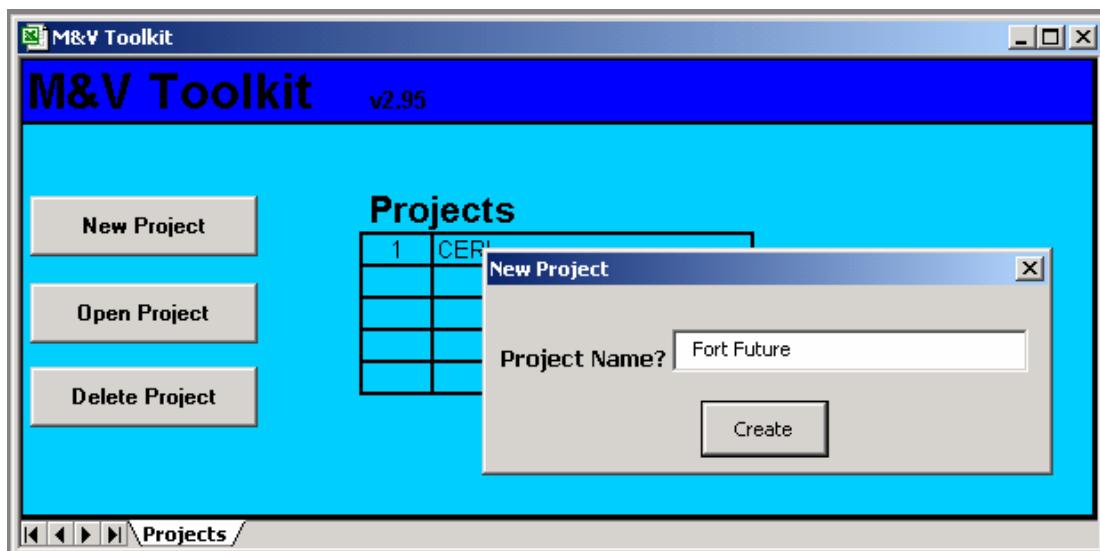


Figure 10. Creating a new project.

The program will copy assorted files to a new project folder and open the Project Manager window, allowing you to begin adding ECMs and data to your project.

Adding an ECM

Use the “New ECM” button to add ECMS to a project. This will show a pop-up window (Figure 11) that allows you to select an ECM from a dropdown menu, or to type a custom name for your own ECM (which must adhere to the same naming conventions described above). Here you also select whether data for this ECM will be collected using data loggers or an EMCS, or whether the data will be taken from the building’s utility bill. The construction cost of this ECM should also be entered here. This number does not need to be exact; it is used only to estimate M&V cost as a percentage of project construction costs. When you have entered all this information, click “Create.” Your ECM will now be visible in the ECM list in the Project Manager.

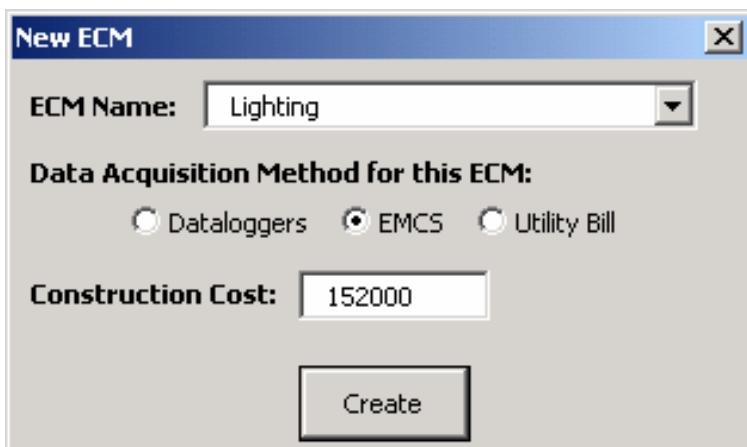


Figure 11. Adding an ECM to a project.

Entering Project-Level Cost Data

Click the “Input Data” button to begin entering cost information for your project. There are two types of data for a project: project level and ECM level. Project level data is cost information that remains the same throughout the project and that does not depend on the ECM, method, etc. The Input Data window contains a tree that allows you to select what data you would like to enter (Figure 12). By clicking the “+” next to an item in the tree, you can expand it to locate a specific subfolder containing a data sheet that needs completion.

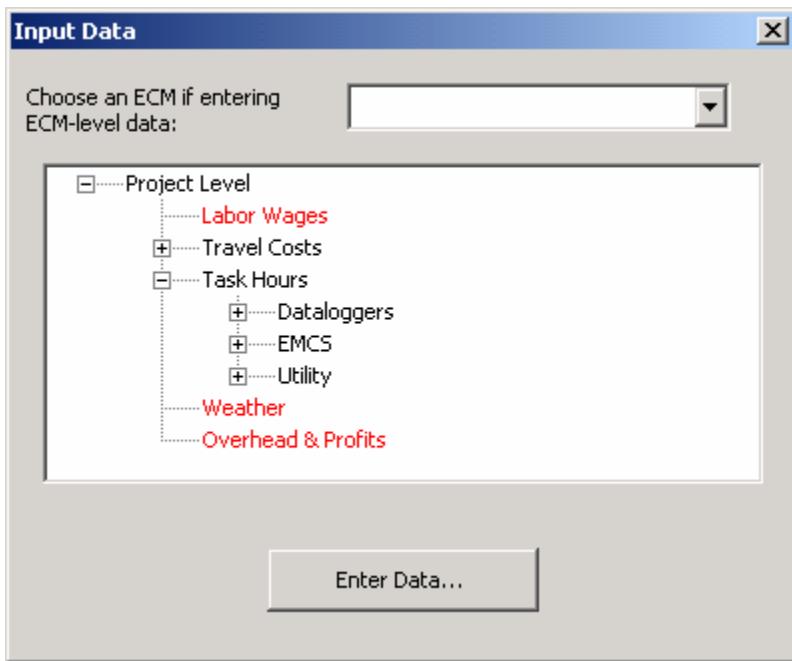


Figure 12. The Input Data window.

If you have not entered data in a certain category, its name will appear red in the tree. Once you have opened a data sheet, its name will become black. (NOTE: If you open data sheets but do not save changes when prompted, it will appear that data has been entered in those categories; the program will not function properly if you then evaluate a report without entering data in this category and saving.) There are five types of project level data:

1. **Labor Wages.** A pop-up window allows you to enter hourly wages for all the personnel that will be working on the project (Figure 13). This menu also lets you enter a fringe benefit percentage that will be added to all employees' wages.

Enter Labor Rates

	\$/hr
Project PI	100
Project CoPI	95
Project Manager I	75
Project Engineer	50
Data Base Support Worker	35
Data Base Manager	50
Programming Manager	75
Field Engineer 1	50
Field Engineer 2	35
Data Base Programmer	35
Data Analyst	50

Fringe Benefit %

Figure 13. Setting wages for laborers.

2. **Travel Costs.** This sheet allows you to enter the costs of traveling to the project site to install, maintain, and remove equipment (Figure 14). The separate data sheets for each method of M&V allow you to specify different travel costs depending on the method of M&V of an ECM. The PreMAP Travel costs are those associated with travel to develop a preliminary monitoring and analysis plan. The installation travel cost is associated with the travel needed to install the monitoring equipment. Maintenance travel costs are those associated with travel to maintain equipment. Equipment removal travel cost is associated with the cost of travel to remove equipment at the end of a project. Use the “Enter Data” button in the upper right to input your numbers. You need not enter data for all the methods, only the ones that will be used by an ECM in your project.

Installation Travel Costs				Maintenance Travel Cost			
	A. Number of Items	B. Number of People, Days, etc.	C. \$/unit		A. Number of Items	B. Number of People, Days, etc.	C. \$/unit
Transportation	5	1	\$100.00	Trave	2	4	\$100.00
Lodging days	5	2	\$100.00	Lodging	2	2	\$75.00
Meals per day	6	5	\$10.00	Mscs	6	2	\$50.00
Misc.	0	0	\$0.00	Msc.	0	0	\$25.00

PreMAP Travel Costs				Equipment Removal Travel Cost			
	A. Number of Items	B. Number of People, Days, etc.	C. \$/unit		A. Number of Items	B. Number of People, Days, etc.	C. \$/unit
Transportation	6	1	\$100.00	Transcriber	2	4	\$100.00
Lodging days	5	2	\$100.00	Lodging	2	2	\$100.00
Meals per day	6	5	\$10.00	Mscs	6	2	\$10.00
Misc.	0	0	\$0.00	Msc.	0	0	\$16.00

Figure 14. The travel cost input data sheet.

3. **Task Hours.** These sheets (Figure 15) are where you enter the amount of time certain tasks, such as data polling or closeout, will take, and who will be performing the labor. There are different sheets for each data acquisition method and M&V method. Once again, you need only enter data for the combinations that will occur in your project. Once you have opened the desired sheet, use the “Enter Data” button to input your data.

Other Installation Costs				C. Admin/unit			
Item	Units	A. \$/Unit	B. No. Units	Hrs	\$/hr		
PreMAP		\$0.00	1	12			
Parts ordering, etc.		\$0.00	1	20			
Other							

Polling, QC and Data Entry Costs			
Item	Unit		
Setup Costs	Per Channel		
Polling Costs	Per Logger		
QC Database Load	Per Channel		
Data Cleaning	Per Channel		
Computer Maintenance	Per Month		
Other			

Data Recovery/Missing Data				Reporting			
Item	A. Unit	C. Labor	D. Admin/unit	Item	Unit	Labors	Admin/unit
		Data Base Support Worker		Project PI			
		Hrs	\$/hr	Hrs	\$/hr		
Data Recovery	Per Channel	0	\$10	1	\$16		
Missing Data	Per Channel	0	\$10	1	\$16		
Other		0		0			

One Time Baseline/Post Retrofit Analysis				Close-out, Data Transfer			
Item	Unit	Labors	Admin/unit	Item	Unit	Labors	Admin/unit
		Data Analyst		Project PI			
		Hrs	\$/hr	Hrs	\$/hr		
Setup Costs		2		1			
Report Generation Costs		0.5	\$58	0.25	\$116		
Other		0		0			

Figure 15. Entering task hours information for an ECM.

4. **Weather.** This pop-up window (Figure 16) is where you enter the supply costs, frequency, and labor hours for the collection of weather data necessary to accurately assess the ECM effectiveness. Once you have entered the quantity, supply costs, and frequency of the tasks, click the “Labor Hours” button to enter the amount of time each task will take for the laborer and project administrator.

	Quantity	Supply Cost	Times Per Yr
Setup Costs	1	1	1
Polling/Transfer	1	1	52
QC, Database Load	1	1	52
Data Cleaning	1	1	1
other	0	0	0

Labor Hours

Done Cancel

Figure 16. Inputting weather data costs.

5. **Overhead and Profits.** This window is where you enter a percentage to accommodate the contractor’s profits and overhead (Figure 17). This number will be multiplied by the entire project cost and added into the final reports.

Enter percentage for contractor's overhead and profits:

17

Save Cancel

Figure 17. Setting the contractor’s overhead and profits percentage.

Entering ECM Level Data

For each ECM you add to your project, you must enter two types of data: equipment and data manipulation costs. You can enter separate equipment lists for the same ECM depending on the M&V method.

Once you have added at least one ECM to your project, click the “Input Data” button. Select the ECM from the dropdown menu at the top, and then expand ECM Level -> Equipment. Click the M&V method that you wish to enter equipment for, and click “Enter Data.”

A new worksheet (Figure 18) will open, on which you can enter all the equipment and associated labor you need for your project.

There are four buttons along the bottom of this sheet:

1. “**Select Personnel**” chooses the laborer and administrator who will be handling the installation, maintenance, and removal of your equipment.

The screenshot shows the 'Equipment: Short M&V - EMCS' window. On the left, there's a table of equipment items with columns for Manufacturer and Name, Price, and Quantity. The first item listed is 'ENERNET Corporation - K20-2' at \$2,490.00 with a quantity of 1. In the center, a modal dialog titled 'Select Personnel' is open, containing dropdown menus for selecting 'Field Engineer' and 'Project PI' for Installation, Maintenance, and Removal. Below the dialog are 'Save' and 'Cancel' buttons. At the bottom of the main window, there are four buttons: 'Select Personnel', 'Select Equipment...', 'Edit Labor Info', and 'Remove Equipment'. The status bar at the bottom shows navigation icons and the path: 'Long M&V > Short M&V < Simulation M&V'.

Figure 18. In the equipment manager, the laborers and administrators for equipment installation, maintenance and removal are selected.

2. “**Select Equipment**” (Figure 19) brings up an interface to easily select and add appropriate equipment. Choose the category of equipment you wish to add from the dropdown menu in the upper left. A list of manufacturers will appear in the left pane. When you select a manufacturer, a list of models will appear on the right. To see details on the model, click the “More Info...” button to invoke a listing of equipment details (e.g., Figure 20). When you are satisfied with your equipment choice, enter a quantity in the indicated box and press “Add.”

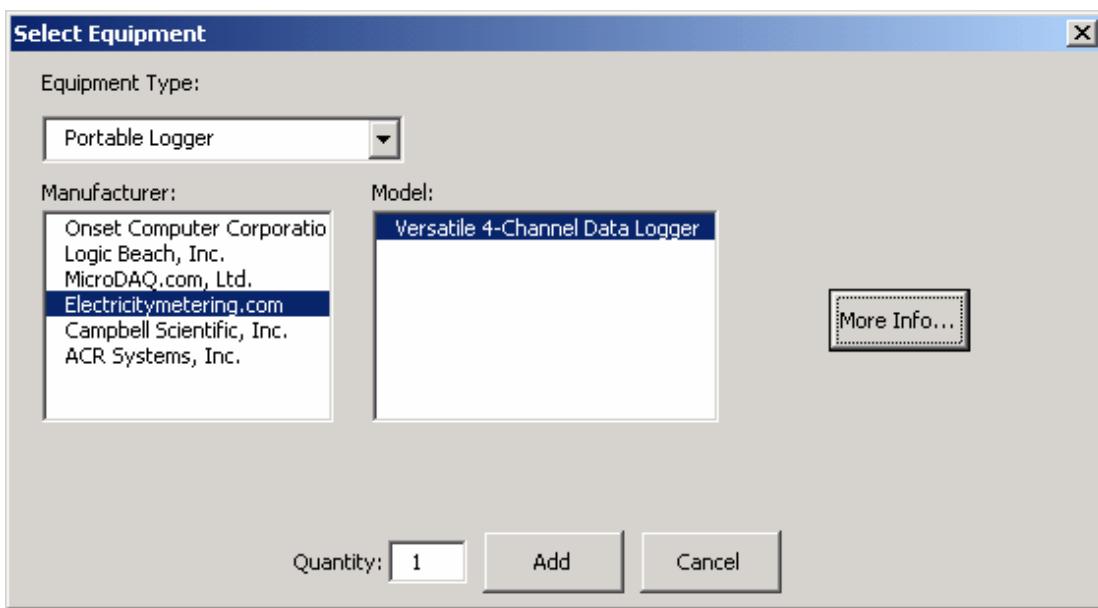


Figure 19. Choosing equipment for an ECM.

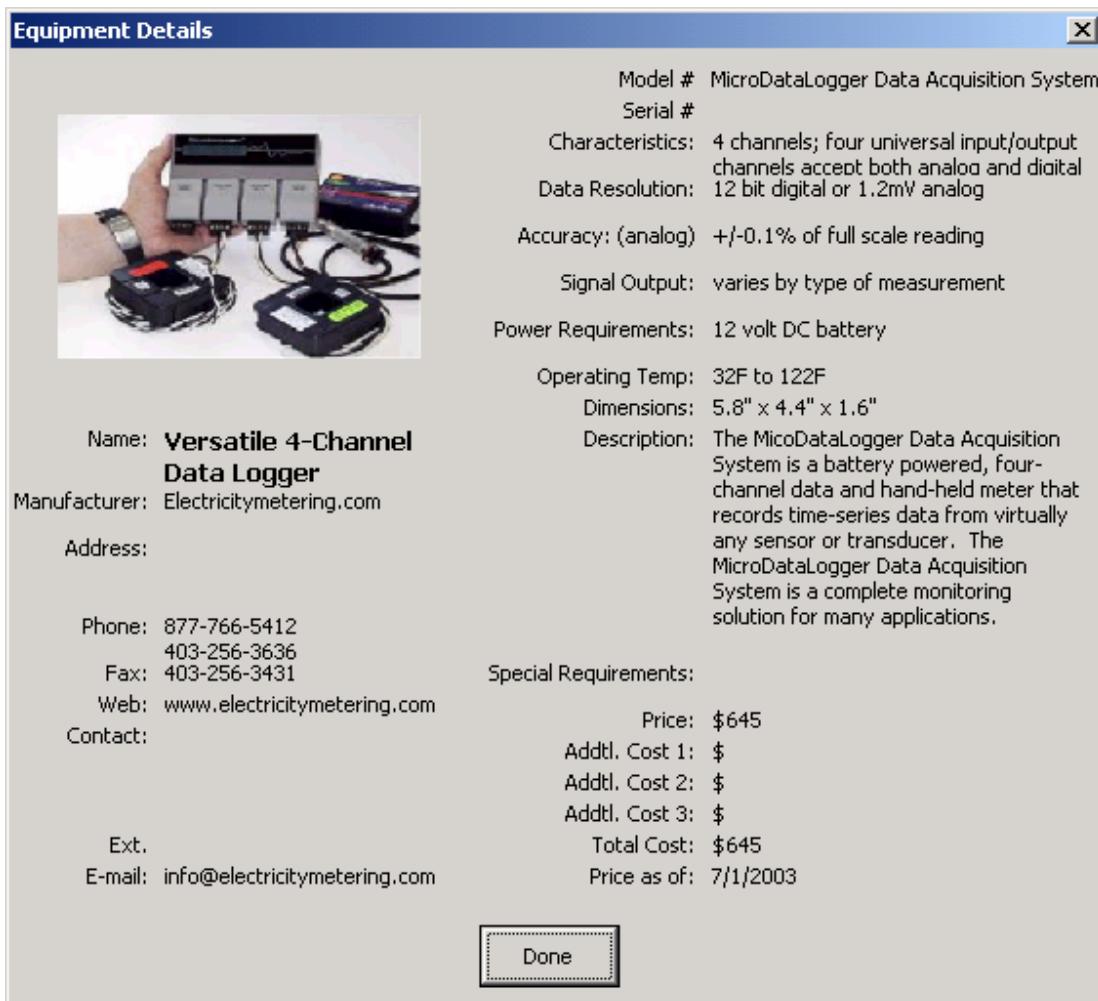


Figure 20. Viewing a detailed description of a piece of equipment.

3. “**Edit Labor Info**” lets you change the number of hours associated with a piece of equipment (Figure 21). When you add a piece of equipment to your project, a default set of labor hours is loaded with it. The numbers represent the number of laborer and administrator hours anticipated for each task, and the percentage of the original purchase price allocated each year for maintenance costs. You can change these by clicking the “Edit Labor Info” button, then by selecting the desired equipment from the dropdown menu. When you are finished, click “Save.”

Installation:	
Field Engineer 1	2
Project PI	0.5

Maintenance:	
Field Engineer 1	2
Project PI	0.2
Parts costs, etc. (% per year of purchase price)	10

Removal:	
Field Engineer 1	4
Project PI	0.2

Save

Figure 21. Modifying the number of hours allotted for tasks for a piece of equipment.

4. “**Remove Equipment**” allows you to delete a piece of equipment from your list (Figure 22). The associated labor will also be removed at the same time.

Select which piece of equipment you would like to remove:

FLEX-CORE - CT1-200

Delete

Figure 22. Removing a piece of equipment.

Once you have entered all the equipment for this M&V method of the ECM, save and close the equipment sheet. If you will be evaluating this ECM for more than one method, be sure to enter equipment for each of them.

The final data you need to enter are the Data Manipulation Costs – costs such as data retrieval, lost data recovery, report generation, etc. (Figure 23). Expand “Data Manipulation Costs” in the Input Data tree (located under ECM Level) and choose the method you will be evaluating this ECM for. (If you will be evaluating for more than one method, repeat the procedure for each.) Click “Enter Data...” and use the “Enter Data” button on the worksheet that opens to complete all the data sets.

The screenshot shows the 'EMCS Data Manipulation Costs' worksheet titled 'Data Manipulation Costs: Long M&V - EMCS'. It includes sections for 'Polling, QC and Data Entry Costs', 'Data Recovery/Missing Data', and 'One Time Baseline/Post Retrofit Analysis'. A modal dialog box titled 'Input Data: Reporting' is open, showing sub-sections for 'Setup Costs', 'Report Generation Costs', and 'Other'. The 'Setup Costs' section has three rows with values: 1, 1, and 12. The 'Report Generation Costs' section has two rows with values: 1 and 12. The 'Other' section has one row with value 0. Buttons 'Done' and 'Cancel' are visible at the bottom of the dialog. The main worksheet background shows tables for 'Ongoing Savings Analysis' and 'Close-out, Data Transfer' with various cost items and their values.

Figure 23. Entering data manipulation costs for an ECM.

Once you have entered in all the data in this worksheet, save and close it. You are now ready to evaluate an ECM.

Evaluating an ECM

Click the “Evaluate ECM” button on the Project Manager if you are ready to evaluate. In the following window, select which ECM and M&V method to compile data for, and click the “Evaluate” button (Figure 24).

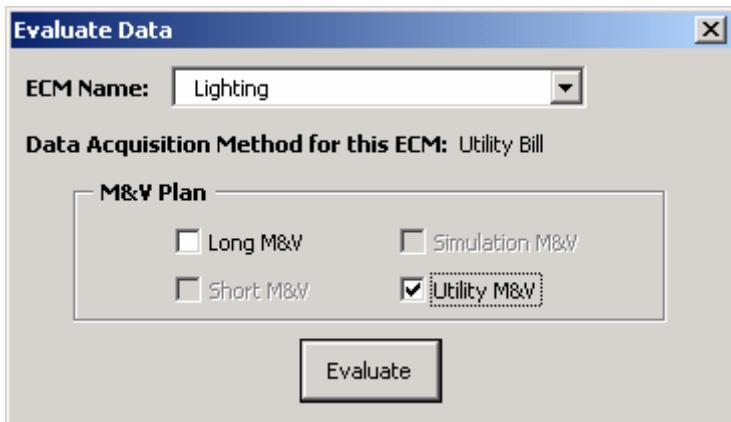


Figure 24. Evaluate Data window.

If you have not entered all the necessary data, then you will receive a message indicating that something is missing. The input data window will then open (Figure 25). Select the ECM for which you were intending to evaluate, and correct the missing information in the yellow-highlighted fields, then re-evaluate.

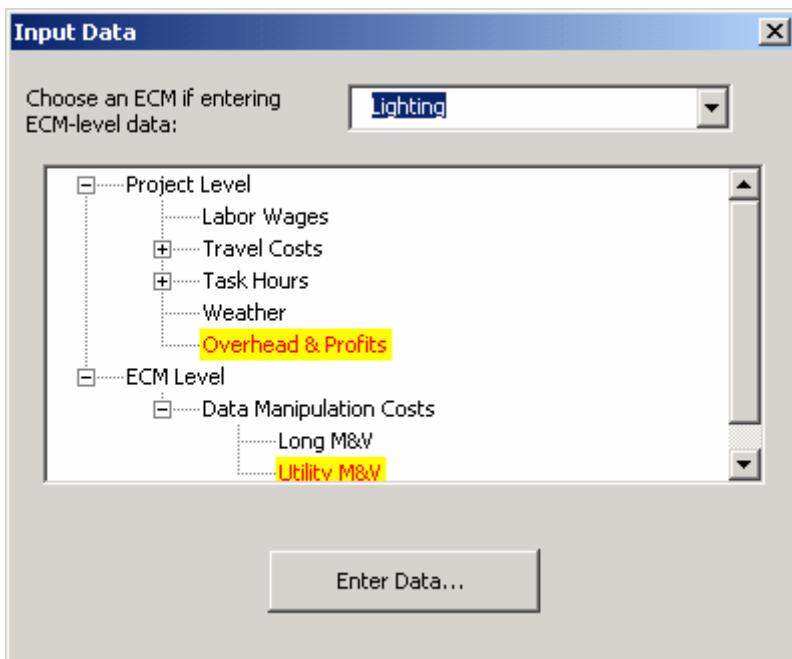


Figure 25. Missing data that must be entered before evaluation.

Evaluation may take several minutes. Please be patient. If evaluation is successful, you will see an x appear in the Project Manager in the row of the ECM, in the column corresponding to the method evaluated.

Changing Data

If at some point after creating an ECM and evaluating it, you decide you want to change one or more of the parameters you entered, feel free to do so. Just remember that, if you change ECM-level data, you must re-evaluate that ECM. If you change project-level data, all ECMs must be re-evaluated for the change to take place.

Viewing ECM Reports

Once you have created an ECM, entered all of the data, and evaluated it, you are ready for your ECM reports. These will give you at-a-glance overviews and detailed summaries of the costs for your ECM. There are nine possible reports for each ECM—an extensive summary for each method and five detailed cost reports (Figure 26).

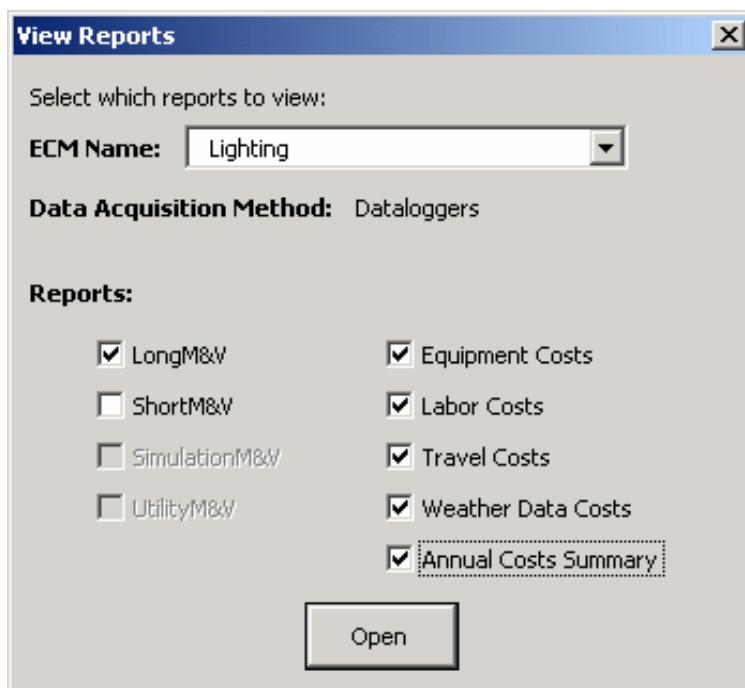


Figure 26. View reports window.

The first four reports (*Long M&V*, *Short M&V*, *Simulation M&V*, and *Utility M&V*) are workbooks that each contain two worksheets. The first is a breakdown of costs by category, such as installation, maintenance, savings analysis, or weather data (Figure 27). The second is the raw compilation of all the input data for the M&V method (Figure 28). This sheet contains extensively detailed information on all the costs associated with an ECM.

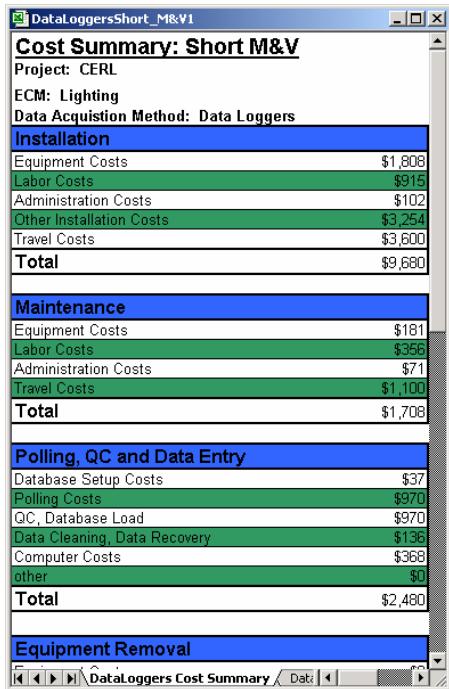


Figure 27. Cost summary by category.

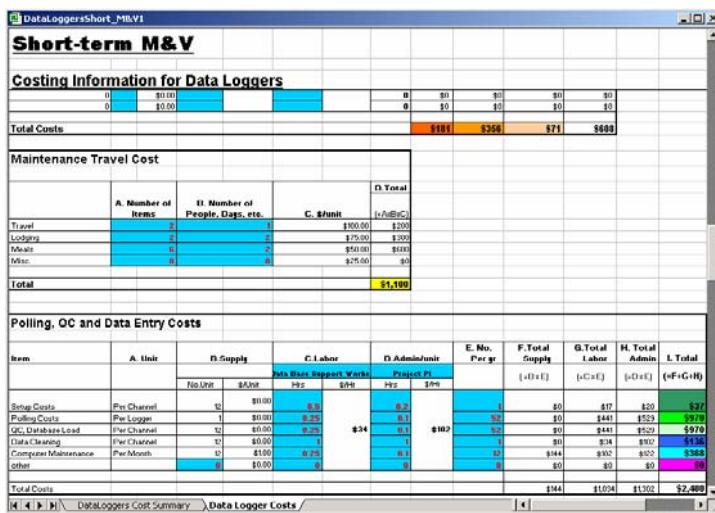


Figure 28. Raw compilation of input data.

The *Equipment Report* (Figure 29) contains the equipment list for the ECM. Use the tabs along the bottom of the workbook to navigate to the M&V method for which you wish to view equipment.

Equipment Costs: Long M&V

Project: CERL
ECM: Lighting
Data Acquisition Method: Data Loggers

Item	Cost/Item	No. Items	Total Cost
ENERNET Corporation - K20-2	\$2,490.00	1	\$2,490.00
FLEX-CORE - CT1-200	\$155.00	4	\$620.00
The Eppley Laboratory - Model 8-48	\$1,400.00	1	\$1,400.00
Total Cost			\$4,510.00

[Navigation icons] Long M&V [Short M&V] [Simulation M&V]

Figure 29. The Equipment report.

The *Labor Report* (Figure 30) contains laborer and administrator costs for each specific task, and is also broken out by first year, annual, and last year labor costs.

Labor Costs: Long M&V

Project: CERL
ECM: Lighting
Data Acquisition Method: Data Loggers

Year one		
Installation	Field Engineer 1	\$1,017.00
	Project PI	\$116.96
	Project PI	\$3,254.40
Maintenance	Field Engineer 1	\$406.80
	Project PI	\$81.36
Polling, QC and Data Entry	Data Base Support Worker	\$1,033.95
	Project PI	\$1,301.76
Data Recovery/Missing Data	Data Base Support Worker	\$542.40
	Project PI	\$203.40
One Time Baseline/ Post Retrofit Analysis	Data Analyst	\$452.00
	Project PI	\$152.55
Ongoing Savings Analysis	Data Analyst	\$632.80
	Project PI	\$711.90
Reporting	Data Analyst	\$361.80
	Project PI	\$406.80
TOTAL		\$10,675.68
Annual		
Maintenance	Field Engineer 1	\$406.80
	Project PI	\$81.36
Polling, QC and Data Entry	Data Base Support Worker	\$1,033.95
	Project PI	\$1,301.76
Data Recovery/Missing Data	Data Base Support Worker	\$542.40
	Project PI	\$203.40
Ongoing Savings Analysis	Data Analyst	\$632.80
	Project PI	\$711.90
Reporting	Data Analyst	\$361.80
	Project PI	\$406.80

[Navigation icons] Long M&V [Short M&V] [Simulation M&V]

Figure 30. Labor cost report.

The *Travel Costs* report (Figure 31) contains a breakdown of travel costs by PreMAP, installation, maintenance, and removal.

Travel Costs: Long M&V

Project: CERL
ECM: Lighting
Data Acquisition Method: Data Loggers

Installation Travel Costs

	A. # of Items	B. # of People, Days, etc.	C. \$/unit	D. Total (=AxBxC)
Transportation	5	1	\$100.00	\$500
Lodging days	5	2	\$100.00	\$1,000
Meals per day	6	5	\$10.00	\$300
Misc.	0	0	\$0.00	\$0
Total				\$1,800

PreMAP Travel Costs

	A. # of Items	B. # of People, Days, etc.	C. \$/unit	D. Total (=AxBxC)
Transportation	5	1	\$100.00	\$500
Lodging days	5	2	\$100.00	\$1,000
Meals per day	6	5	\$10.00	\$300
Misc.	0	0	\$0.00	\$0
Total				\$1,800

Maintenance Travel Cost

	A. # of Items	B. # of People, Days, etc.	C. \$/unit	D. Total (=AxBxC)
Travel	2	1	\$100.00	\$200
Lodging	2	2	\$100.00	\$400
Meals	6	2	\$10.00	\$120
Misc.	0	0	\$16.00	\$0
Total				\$720

Long M&V / Short M&V / Simulation

Figure 31. Travel costs report.

The *Weather Costs* report (Figure 32) gives a line-item overview of the costs of weather data.

Weather Costs

Project: CERL
ECM: Cooling Tower VFD

Hourly Weather Data

Setup Costs	\$82
Polling Costs	\$1,594
QC, Data Load	\$1,594
Data cleaning, Data Recovery	\$48
Other	\$0
Total	\$3,318

Weather

Figure 32. Weather cost report.

The *Annual Cost Report* (Figure 33) provides a first-year, annual, and last-year cost breakdown of all costs for measurement and verification of an ECM. This is one of the most useful reports, which provides a bottom-line M&V cost for the ECM and shows exactly where all the costs come from.

The screenshot shows a software application window titled "DataLoggersAnnualCostsReport1". The main title is "Annual Costs: Long M&V". Below it, project details are listed: Project: CERL, ECM: Lighting, and Data Acquisition Method: Data Loggers. A dropdown menu shows "No. of years: 5".

First Year Costs

	Data Loggers
Installation	\$12,498
Maintenance	\$1,939
Polling, QC and Data Entry	\$2,480
Data Recovery/Missing Data	\$770
One Time Baseline/Post-Retrofit Analysis	\$632
Ongoing Savings Analysis	\$1,589
Reporting	\$781
Data Transfer	\$204
Overheads & Profits	\$3,970
Total	\$24,862

Annual Costs

	Data Loggers
Maintenance	\$1,939
Polling, QC and Data Entry	\$2,480
Data Recovery/Missing Data	\$770
Ongoing Savings Analysis	\$1,589
Reporting	\$781
Data Transfer	\$204
Overheads & Profits	\$1,475
Total(per year)	\$9,238

Last Year Costs

	Data Loggers
Maintenance	\$1,939
Polling, QC and Data Entry	\$2,480

At the bottom, there are navigation buttons: back, forward, and search, followed by "Long M&V" and "Short M&V" buttons, and a page number "5".

Figure 33. Annual cost report.

5 Interpreting Results

This chapter gives a some examples of how cost and accuracy are affected when various ECMs and M&V monitoring methods are considered.

Lighting Retrofit

In a large lighting retrofit project, most or all of the lighting fixtures in a building may be replaced. Table 1 lists sample M&V estimations for a lighting retrofit. The short, utility, and simulation methods assume 1 year of monitoring, while the long method assumes 3 years of monitoring. The simulation method is the most expensive, yet not exceedingly accurate. The utility method is by far the cheapest, but the accuracy of utility bill analysis could be questionable if the effect of the lighting retrofit is not drastic with respect to energy reduction. The short and long methods have similar costs. The long method is roughly \$8,000 more than the short method since it includes two additional years of travel and maintenance costs, as well as yearly reports. Since the energy consumption of lighting is likely to remain relatively constant over time, a short term M&V plan would likely be a good balance between cost and accuracy.

Boiler Insulation

Table 1 shows sample M&V cost estimations for the boiler insulation ECM. The short method is a 1-year plan; the long, utility, and simulation methods are 3-year plans. The simulation method is again the most expensive, and again the accuracy of the simulation can be questionable. The utility method is the cheapest, and could be appropriate if the insulation will dramatically reduce energy usage. The long and short method costs are comparable, although the long plan is about \$10,000 more expensive since it was run as a 3-year plan. Since the running conditions of the boiler will change over time depending on weather conditions, it may be appropriate to use the long method for added accuracy. If great accuracy is not needed, the short or utility method would trade off accuracy for reduced cost.

Table 1. Sample M&V estimations for different ECMs and M&V monitoring methods.

ECM	Short		Long		Utility		Sim.	
	1 st Yr.	Total	1 st Yr.	Total	1 st Year	Total	1 st Yr.	Total
Lighting Retrofit	22,759	34,348	22,182	42,485	1,467	2,776	30,097	49,375
Boiler Insulation	28,144	43,041	27,714	53,347	1,467	4,004	35,482	77,368
Cooling Tower VFD	24,833	38,174	24,403	67,517	1,467	6,460	32,171	107,791

Cooling Tower VFD

Table 1 also includes the same M&V cost estimations for the cooling tower VFD ECM. The short method is a 2-year plan, the long, utility, and simulation methods are 5-year plans. The total cost of the simulation plan is a little less than double the total cost of the long method, and the drop in accuracy from the long to the simulation method would probably not make simulation worth the cost. As with a boiler insulation ECM, the energy data of the VFD will vary with time, which means that the added cost of running a long method M&V plan could make the added accuracy worth the cost. If the energy conditions of the VFD are expected to remain relatively constant, then the short method would be more cost effective and would provide a good amount of accuracy. The utility bill method is the cheapest method, appropriate to use if the VFD is expected to have a dramatic effect on energy savings.

6 Compiling and Viewing Project Level Reports

Once you have entered all of your ECMS into the project and evaluated them, you may wish to see an overview of your entire project. The “Project Report” button allows you to select which ECMS to include in your final project report (Figure 34), and also allows you to choose a specific M&V option if an ECM has been evaluated for more than one (Figure 35). When you click the “Project Report” button, a window will open and a list of all the ECMS in your project will be visible. Use the buttons in the middle to add the desired ECMS to the list on the right, then press “Next.”

You will then see the list of ECMS you chose. Pick the method of M&V you wish to choose for each ECM from the corresponding combo box next to it. If you wish to go back to add or remove ECMS from the report, then click “Back.” If you are satisfied, press “Compile.”

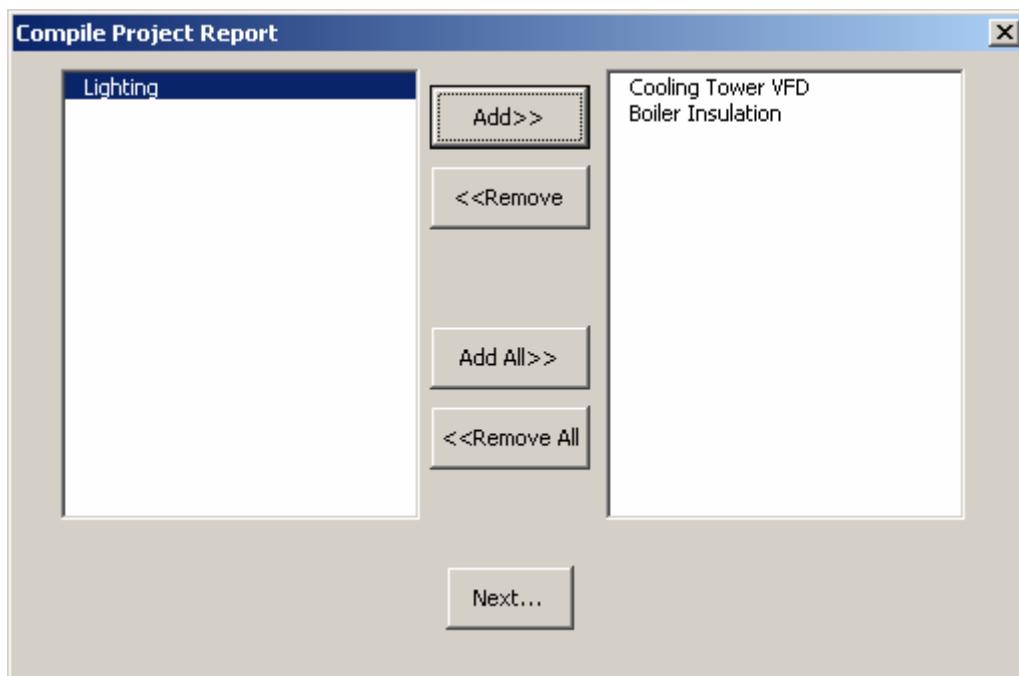


Figure 34. Selecting ECMS to include in the Compile Project Report window.



Figure 35. Selecting the M&V method for each ECM in the project report.

Once you have compiled the report (which may take up to a minute or so) it will open. This report workbook contains five worksheets, visible by the tabs at the bottom of the screen.

The first sheet is the *Project Summary* (Figure 36), which lists each ECM, its M&V cost, the approximate percentage of the construction cost that M&V represents, and the number of years of the contract. It also has these bottom-line numbers for the entire project.

Project Report.xls						
Project Summary: CERL						
ECM	Data Acquisition Method	M&V Plan	No. Years	Total ECM Cost	Construction Cost	% M&V
Cooling Tower VFD	Dataloggers	Long M&V	3	\$35,454	\$500,000	7.1%
Boiler Insulation	Dataloggers	Long M&V	3	\$29,693	\$246,000	12.1%
SubTotal						
				\$65,147		
Weather Costs			3	\$11,238		
Travel Costs			3	\$4,320		
Total				\$80,705	\$746,000	10.8%

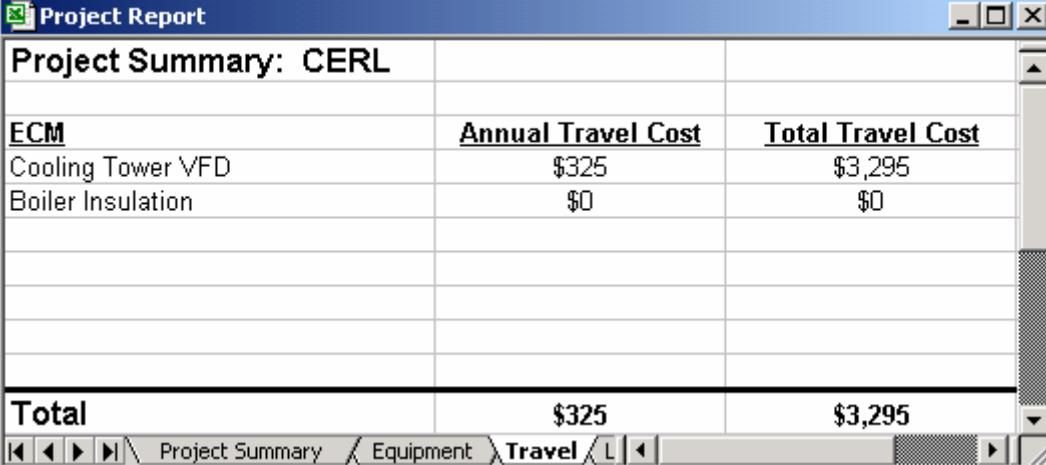
Figure 36. The Project Summary.

The second sheet, the *Project-Level Equipment Summary* (Figure 37), lists the equipment costs for each ECM.

Project Report	
Project Summary: CERL	
ECM	Equipment Cost
Cooling Tower VFD	\$645
Boiler Insulation	\$0
Total	\$645

Figure 37. Equipment costs for the entire project.

The third project-level report available is a *Travel Report* (Figure 38). It contains a line for the annual costs and total costs related to travel for each ECM, and totals them for the entire project.

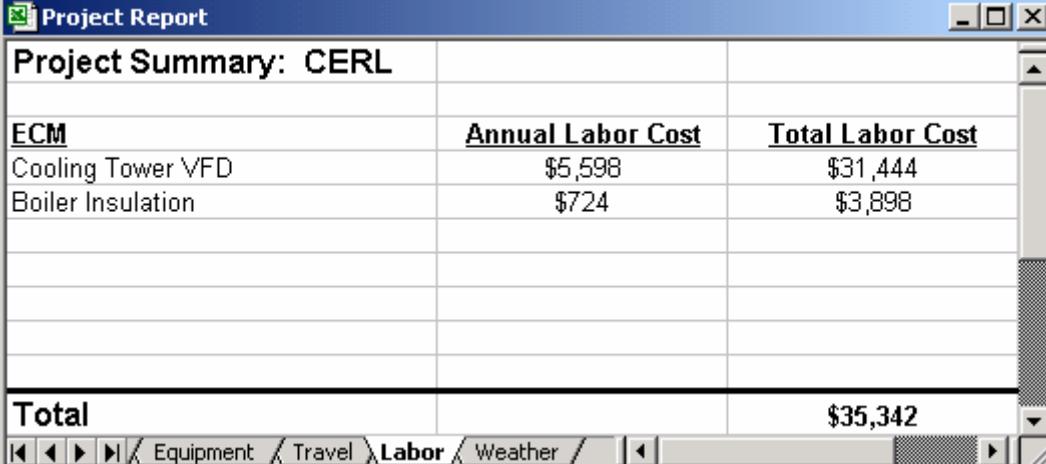


The screenshot shows a software window titled "Project Report" with a title bar "Project Summary: CERL". The main area is a table with three columns: "ECM", "Annual Travel Cost", and "Total Travel Cost". There are two rows of data: one for "Cooling Tower VFD" with an annual cost of \$325 and a total of \$3,295, and another for "Boiler Insulation" with an annual cost of \$0 and a total of \$0. A bold "Total" row at the bottom shows a total annual travel cost of \$325 and a total travel cost of \$3,295. The bottom navigation bar shows the path: Project Summary > Equipment > Travel.

ECM	Annual Travel Cost	Total Travel Cost
Cooling Tower VFD	\$325	\$3,295
Boiler Insulation	\$0	\$0
Total	\$325	\$3,295

Figure 38. The travel costs summary for the whole project.

The next sheet in the Project Report is a *Labor Report* (Figure 39). Once again, this has the annual and total labor costs for each ECM broken out, and the totals for the entire project.

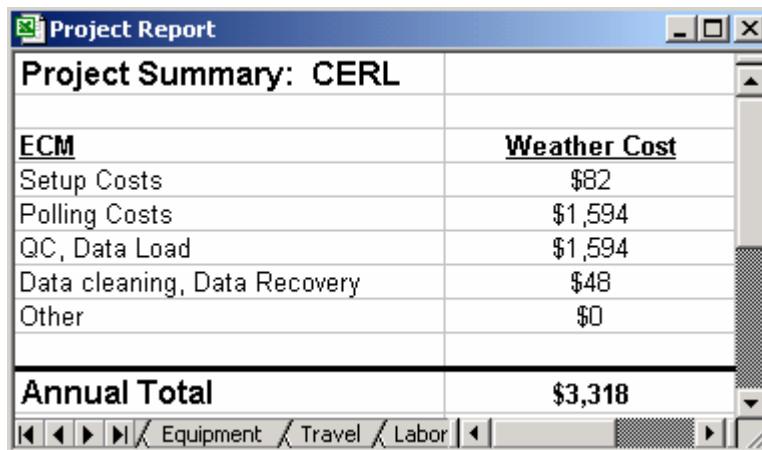


The screenshot shows a software window titled "Project Report" with a title bar "Project Summary: CERL". The main area is a table with three columns: "ECM", "Annual Labor Cost", and "Total Labor Cost". There are two rows of data: one for "Cooling Tower VFD" with an annual cost of \$5,598 and a total of \$31,444, and another for "Boiler Insulation" with an annual cost of \$724 and a total of \$3,898. A bold "Total" row at the bottom shows a total annual labor cost of \$35,342. The bottom navigation bar shows the path: Project Summary > Equipment > Travel > Labor > Weather.

ECM	Annual Labor Cost	Total Labor Cost
Cooling Tower VFD	\$5,598	\$31,444
Boiler Insulation	\$724	\$3,898
Total		\$35,342

Figure 39. The project-level labor report.

The final worksheet in the Project Report Workbook is the labor cost summary (Figure 40). This sheet outlines the costs for hourly weather data used to monitor all your ECMs.



Project Summary: CERL	
ECM	Weather Cost
Setup Costs	\$82
Polling Costs	\$1,594
QC, Data Load	\$1,594
Data cleaning, Data Recovery	\$48
Other	\$0
Annual Total	\$3,318

Figure 40. Annual weather costs summary in the Project Report.

7 Summary

In the past, many energy savings projects contained minimal M&V activities, partially because of the difficulty in estimating M&V costs and determining the most cost effective M&V method. While several Standards and guidelines for M&V activities exist, none adequately guides the reader in estimating and comparing those costs.

This work has developed the user-friendly M&V Toolkit, a utility that estimates M&V costs. The costing toolkit presented here is not unique in its approach to the M&V methods. It is unique, however, in that it approaches M&V methods from the standpoint of how M&V data is gathered (short term, long term, utility bills, temporary data loggers, permanent data loggers, EMCs). The Toolkit helps users determine the monitoring method that will provide necessary data at an acceptable cost.

The toolkit estimates costs for four M&V methods:

1. A long-term analysis
2. A short-term analysis
3. A monthly utility bill analysis
4. A calibrated simulation model.

It is recommended that the M&V Cost Estimating Tool be used for future energy savings projects, especially those financed by Energy Savings Performance Contracts.

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Glossary

annual costs

Labor, equipment, and supply costs that recur every year an ECM is being monitored.

ASHRAE Guideline 14

A detailed set of procedures developed by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers to standardize energy savings measurements and calculations.

baseline

The energy or resource usage of a facility before a retrofit. Post-retrofit data is compared to the baseline to determine energy savings.

DAQ – Data Acquisition method

DAQ refers to the method of collecting monitoring data for an ECM or project. The toolkit offers three options: (1) using dataloggers, (2) using an existing EMCS panel, or (3) taking data from the utility bill.

data manipulation

Refers to a set of tasks such as data transfer, missing data recovery, ongoing savings analysis, reporting, and closeout. These tasks are performed for each ECM in the project, and are edited on an individual-ECM basis. This allows the user to specify, for example, monthly reports for one ECM and bimonthly for another in the same project.

DOE

Department of Energy.

ECM – Energy Conservation Measure

An equipment modification or retrofit, load adjustment, or other measure intended to reduce energy or resource consumption or demand.

EMCS

Energy Management and Control System. A networked system of direct digital control capable hardware used to monitor and control building systems, especially HVAC.

ESCO – Energy Service Company

A company that provides energy and resource conservation solutions to a facility. The ESCO usually designs and implements ECMs, and in some cases is responsible for maintaining and monitoring the measures.

FEMP

The Department of Energy's Federal Energy Management Program works to reduce the cost and environmental impact of the Federal government by advancing energy efficiency and water conservation, promoting the use of distributed and renewable energy, and improving utility management decisions at Federal sites. Note: this definition was taken from the FEMP website:

<http://www.eere.energy.gov/femp/>

IPMVP

The International Performance Measurement and Verification Protocol provides an overview of current best practice techniques available for verifying results of energy efficiency, water efficiency, and renewable energy projects in commercial and industrial facilities. It may also be used by facility operators to assess and improve facility performance. Note: this definition was taken from the IPMVP website

<http://www.ipmvp.org/>

M&V

Measurement and Verification. Specifically, M&V refers to assessing the efficiency improvements delivered by ECMs and verifying that the actual savings correspond to those expected (and often guaranteed by the ESCO).

M&V Plan

For definitions of these methods see the FEMP M&V Guidelines available at

<http://www.eere.energy.gov/femp/financing/espcl/measguide.html>

or by calling 1-800-DOE-EREC.

Long

Collection and analysis of data over a period of several years

Short

Collection and analysis of data over a period of several months

Simulation

Computer simulation of a building used to estimate a project's energy savings

Utility

Analysis of utility bill data to determine energy savings

macro

A unit of Visual Basic code that performs a task or tasks automatically. The toolkit invokes many macros to handle input and compilation of cost data to simplify the process of estimating M&V costs.

module

A collection of one or more Visual Basic macros and functions. Using modules provides additional functionality, allowing a coder to set the scope of variables throughout a project. Modules also allow more organized and easier to follow code.

PreMAP

Preliminary Monitoring and Analysis Plan

retrofit

A replacement of equipment in a facility often performed to reduce energy consumption or demand. A retrofit usually involves replacing old, outdated equipment with newer, more advanced technology.

task hours

A collection of data containing the labor and administration personnel and the number of hours required for several common tasks in a project, such as parts ordering and data manipulation.

VFD

Variable Frequency Drive. A VFD controller is used on an electric motor to vary the power supply frequency, which allows the rotational speed of the motor to be controlled. The motor's RPM can be tuned to exactly what is necessary for the current load.

Appendix: Formulas and Macros

This chapter describes in technical detail how the various workbooks in the toolkit interact, and gives a description of the Visual Basic macro code. The bulk of the code is contained within two Microsoft® Excel workbooks: M&V Toolkit.xls, and Project Manager.xls.

M&V Toolkit.xls

This workbook contains eight code modules. The main modules are described below beginning with the “Sheet1(Projects)” module.

Sheet1(Projects)

The “Sheet1(Projects)” module contains the main code in this workbook. When one of the three buttons on the Projects worksheet is clicked, the code corresponding to that button in the “Sheet1(Projects)” module is activated. These procedures initialize the user forms and then display the forms to the screen, at which point the code execution switches to the specific form that has been activated.

projectNameForm

The “*projectNameForm*” user form code is responsible for creating a new project. The beginning of the module contains some error handling features. The macro then creates the appropriate directories and copies default files to the new locations.

openProjectForm

The “*openProjectForm*” user form opens the selected project’s Project Manager.xls workbook.

deleteprojectform

The “*deleteprojectform*” user form deletes the selected project directory from the M&V Projects folder. The deletion will remove all files and directories associated with the selected project.

ThisWorkbook

The “*ThisWorkbook*” module contains formatting code to modify the appearance of the worksheet.

ErrorHandling

The “*ErrorHandling*” module creates an error report if an error occurs during the execution of a macro.

Project Manager.xls

The heart of the toolkit is the project manager. This workbook contains a number of code modules. The main code, and the interaction among various workbooks, is described below.

The Project Manager has six buttons, each of which triggers a different macro when clicked. Each time a button is clicked, the first thing that happens is that program flow jumps from “Sheet1(Main)” to the workbook’s “Main” module where public variables are declared and assigned. Next, the form corresponding to the button is activated and shown on the screen. From there, program flow is different for each button.

The first button is the “New ECM” button. After public variables are declared and assigned by the “Main” module, execution jumps to the “*NewEcmForm*” code, then to the “*SetupNewEcm*” module. The code copies the appropriate files to the proper directories and adds the ECM to the list in the Project Manager.

The second button is the “Input Data” button. After public variables are declared and assigned by the “Main” module, execution jumps to the “*InputDialogForm*” code, then to the “*InputDialog*” module. The code opens the appropriate workbook based on the user’s selection on the input data form.

The third button is the “Evaluate ECM” button. After public variables are declared and assigned by the “Main” module, execution jumps to the “*Evaluate-*

Form” code, then to the “GetWorkbooks” module, then to the “Evaluation” module. The code first assimilates all of the data input by the user into a single summary workbook (which depends on the M&V method and data acquisition method). Next, the macro disseminates the data from the summary book to several useful reports. All of the data manipulation is done using named ranges in the Excel worksheets.

The fourth button is the “Remove ECM” button. After public variables are declared and assigned by the “Main” module, execution jumps to the “RemoveEcm-Form” code. The macro permanently deletes all of the ECM level data associated with the selected ECM.

The fifth button is the “ECM Reports” button. After public variables are declared and assigned by the “Main” module, execution jumps to the “ReportForm” code, then to the “ViewReports” module. The macro opens the selected report(s).

The sixth button is the “ProjectReports” button. Once again, after public variables are declared and assigned by the “Main” module, execution jumps to the “CompProjRep” code, then to the “GetProjWorkbooks” module, then to the “ProjectEvaluation” module. The macro dynamically calculates the cost of a project based on the selected ECMs and the length of time they each will be monitored. Following this, the macro copies these costs into the Project Report workbook, yielding a concise summary of the project.

Additional code that provides visual and practical enhancements is located in the “ErrorHandling” module, the “Formatting” module, the “Navigation” module, the “TreeNodes” module, and the “ThisWorkbook” module. The “ErrorHandling” macro is called when a runtime error occurs during execution in the toolkit. The macro creates a time-stamped entry in an error log file and displays a message to the user indicating that an error has occurred. The “Navigation” module creates and dynamically updates a menu in the “Window” menu at the top of the screen. This menu allows a user to activate any available report for a project if that report is open. The “TreeNodes” module is called every time the input data window is shown. This module is responsible for populating the list of data to input and color-coding the entries. It works off of a hidden matrix in the Project Manager file that keeps track of all the ECMs and what data has been entered. The “ThisWorkbook” code contains maintenance functions that run on the opening and closing of the Project manager

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